AURAL DETECTION PERFORMANCE OVER A 129 MINUTE SIMULATED SONAR WATCH

by

Joseph S. Russotti
and
Ronald E. Greeb, ST1(SS)

NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

REPORT NUMBER 754

Bureau of Medicine and Surgery, Navy Department
Research Work Unit MF51.525.004-9010DA5G.25

Transmitted by:

J. Donald Harris, Ph. D.
Head, Auditory Research Branch

Reviewed and Approved by:

Charles F. Gell, M.D., D.Sc.(Med)
SCIENTIFIC DIRECTOR
NavSubMedRschLab

Approved and Released by:

R. L. Sphar, CDR MC USN
OFFICER IN CHARGE
NavSubMedRschLab

SUMMARY PAGE

THE PROBLEM

The problem of operator fatigue and its possible effects in reducing the detection performance of the man-machine system was investigated during the course of a 129-min simulated sonar watch.

FINDINGS

Successive measurements on the same non-alerted contact taken 43, 86 and 129 min into the detection period showed no significant change in initial detection from one another, nor from pretest values taken the day before. These results indicate that under conditions where the operator's vigilance is maintained by a not-unusual frequency of contact (operators were presented six contacts at random intervals during each 43 min-period), and where operators are not aware of actual elapsed time, no change in operator initial detection performance is encountered.

APPLICATION

The information presented in this report will be useful to all personnel involved in sonar watchstanding and researchers concerned with sonar operator aural detection.

ADMINISTRATIVE INFORMATION

This investigation was conducted as part of Bureau of Medicine and Surgery Research Work Unit MF51.524.004-9010DA5G — Optimization of Auditory Performance in Submarines. The present report is No. 25 on this work unit. It was submitted for review on 20 July 1973, approved for publication on 12 September 1973 and designated as NSMRL Report No. 754.

The authors wish to acknowledge the invaluable assistance provided by Paul F. Smith and STC Barry F. Cole, NSMRL.

PUBLISHED BY THE NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

ABSTRACT

Experienced sonar operators were exposed to conditions of simulated sonar watchstanding over a 129-min period. Successive measurements on the same non-alerted contact taken every 43 min during the detection period showed no significant change in initial detection. These results indicate that under conditions where the operator's vigilance is maintained by a not-unusual frequency of contact (operators were presented six contacts at random intervals during each 43-min period) no change in operator initial detection performance is encountered.

AURAL DETECTION PERFORMANCE OVER A 129 MINUTE SIMULATED SONAR WATCH

INTRODUCTION

In the realm of passive sonar, though numerous types of semiautomatic detection systems have been explored, systems employing aural detection capabilities of the human operator for decision making still are unsurpassed. Granted that such performance may be further optimized with various methods of multi-modal or encoded signal presentation, the fatigability of the operator must be recognized as the weakest link. Theoretical predictions based upon pure-tone signal detection would indicate that, at least from an auditory point of view, the ear would not be fatigued after exposure to moderate level tones in noise for periods of upwards of 2 hrs. Still, the problem of operator fatigue and its possible effects of reducing the detection performance of the sonar system must be considered.

Fatigue can, of course, be an overall encompassing term. Operators can become "fatigued" from too many contacts (confusion) or too few (boredom). Evaluation of such performance in terms of extremes in conditions cannot in all cases be conducted successfully in the laboratory because of motivational differences between "real world" and obviously contrived experimental situations. For example, while under actual shipboard conditions a sonar operator would willingly stand watch for a 1 hr period during which no contacts were detected, these same conditions in a laboratory situation would obviously not maintain the same motivational level.

While it would be less than ideal to have a trained sonar operator participate in an experimental situation where he is presented no information (contacts) until a 2-hr period has elapsed, successive measures of his performance under different levels of contact density would be of definite value in predicting time limits of maximal operator detection performance.

For the present experiment a medium contact density was chosen, six during three successive 43-min sessions. Under these conditions, the same stimulus was repeatedly presented as the sixth contact of each session and successive measures of operator performance on this contact were taken.

METHOD

Subjects

Eighteen experienced submarine STs were evaluated in the present study; eight of these were SSN, seven SSBN, and three SS, all sampled from operating ships.

Procedure

Operator detection performance was collected using a passive sonar simulator developed at NUSC (Fig. 1). The simulator consisted of a sonar stack or console equipped with a standard handwheel and linked to a specially designed attenuator. This attenuator, more spe-

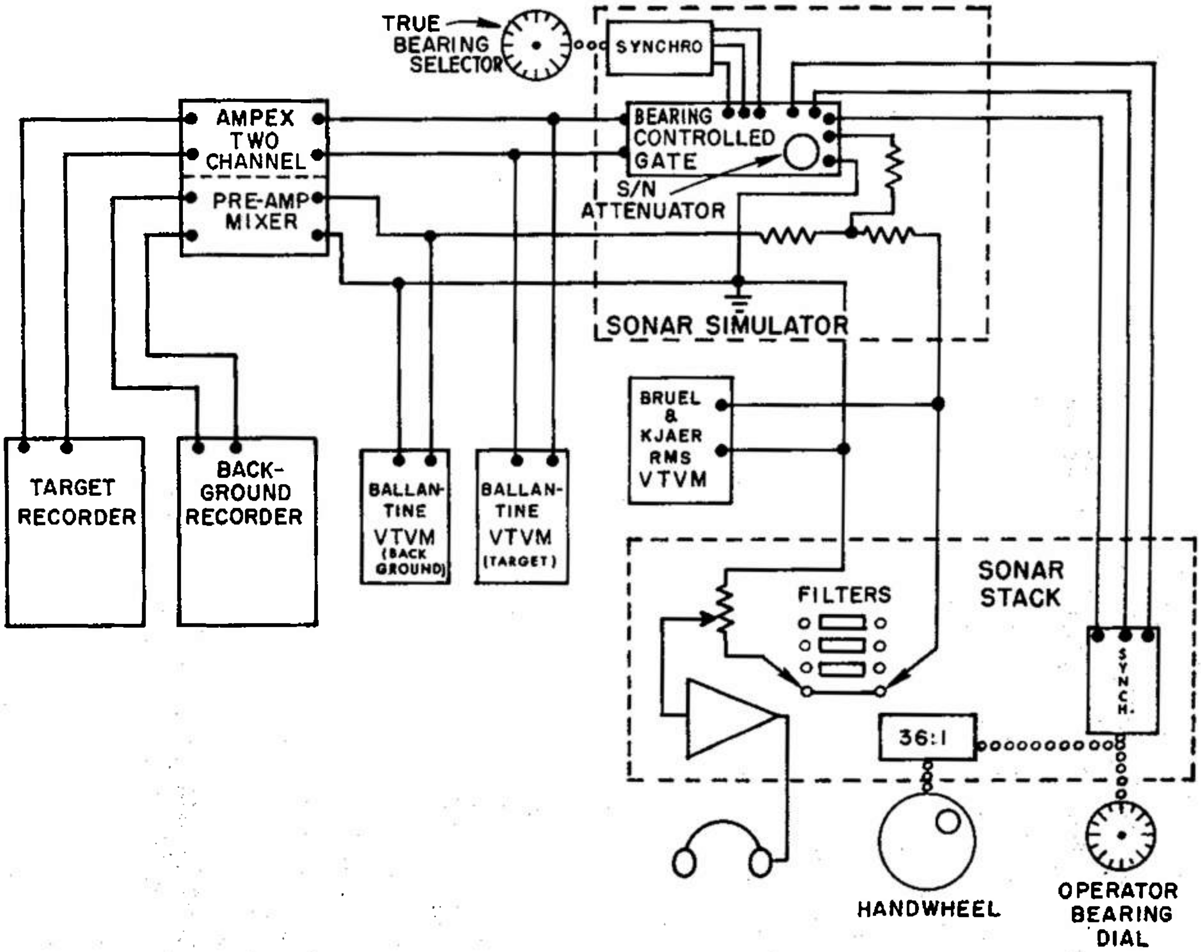

Fig. 1. Block Diagram of Passive Sonar Simulator System

cifically a bearing controlled gate (BCG), gradually permitted the amplitude of the target signal to rise as the operator trained the handwheel nearer to some "preset" bearing 0-360°. Theory of operation of the BCG circuit is available in USL Technical Memo 1210-40-56. The bearing at which the target level reached maximum gain could be selected by the experimenter (E) and the rate of increase in target amplitude per degree bearing was symmetrical about that point such that an equal number of degrees on either side of the selected bearing would produce equal levels of target attenuation. Figure 2 shows the actual response of the system to a white noise signal fed into the target channel only, with a "true" bearing of 40° set on the control synchro. As seen in the figure, a 32-dB attenuation in target intensity was produced symmetrically 36°

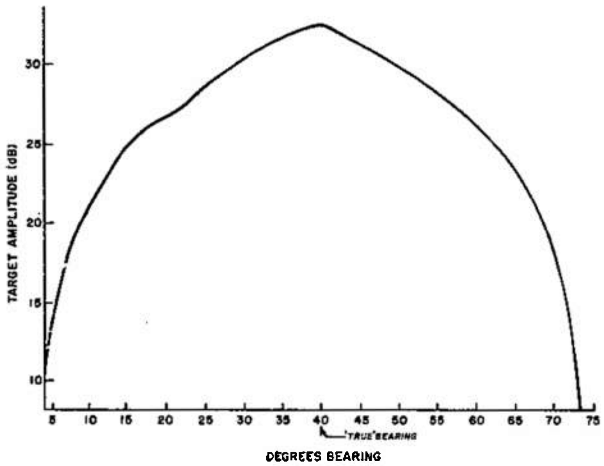

Fig. 2. Measured Response Characteristic of Sonar Simulator Target Channel ± 37° from "True" Bearing.

on either side of "true" bearing, as the operator's handwheel was trained over that selected bearing, causing the target signal to rise out and fall back into the background in which it was masked over a total conduction angle of 72°.

At constant amplitude from 0°-360° on the handwheel was a background signal into which the target was mixed ((when the bearing was appropriate). A step attenuator on the target input permitted the level of the target to be adjusted to some level X dB below the background, so that at "true bearing" the maximum target signal level mixed with the background noise produced a negative S/N ratio. Meters on the equipment allowed E to monitor the number of times the operator swept across the target, a criterion of three sweep passes being required before detection was considered "missed" and the target presented to the operator at the next easier S/N ratio. An accuracy of ±5° was required for the detection to be considered correct.

Targets and background channels of the sonar simulator were fed by tape recorders, Ampex mixers permitting various tape inputs selected by E to be presented over the target channel without alerting the operator. Table 1 presents the schedule of target presentation over three 25-min periods.

Fifteen different stimuli consisting of five types of complex noise were randomly arranged within this schedule and recorded at varying rise and fall times onto standard 1/4-inch recording tape. These stimuli were synthesized to be of arbitrarily chosen spectral character but were easily distinguishable by the operators into five categories. A separate channel was provided with time information to allow E to preset randomized bearings prior to the onset of the contact and manipulate their S/N's.

So as to eliminate any possibility that the particular sequence of contact stimuli preceding our measurement periods would in anyway bias or influence performance on the measurement periods following it, the order of sessions A, B, C was appropriately counterbalanced* across operators and each was presented followed by measures of operator detection performance, the latter occupying 17 to 18 min. Figure 3 depicts this schedule.

**The order of sessions A, B, C, were arranged such that every combination of the 3 was exhausted (6: ABC, ACB, BCA, BAC, CAB, CBA). Once averaged over our 18 operators then, an equal number would have heard these sessions in different order, so that only the effects of successive measurement during the watch would be capable of affecting performance.*

Table 1. Schedule of Contacts

Contact Duration (min)		Rise/Fall (sec)	Pause Before Next Contact (sec)
SESSION A - Total Contact Durations 22:0, Pauses 3:0 : Total = 25 min			
Target 1	6	60/90	20
Target 2	3	30/15	10
Target 3	5	30/60	70
Target 4	5	45/15	80
Target 5	3	0/15	STOP
SESSION B - Total Contact Durations 22:50, Pauses 2:10 : Total = 25 min			
Target 1	4:50	30/20	40
Target 2	5	40/20	20
Target 3	3	60/60	50
Target 4	6	60/30	20
Target 5	4	20/20	STOP
SESSION C - Total Contact Durations 23:40, Pauses 1:20 : Total = 25 min			
Target 1	4:30	30/10	0
Target 2	3	40/20	50
Target 3	6	50/50	20
Target 4	7	0/40	10
Target 5	3:10	10/10	STOP

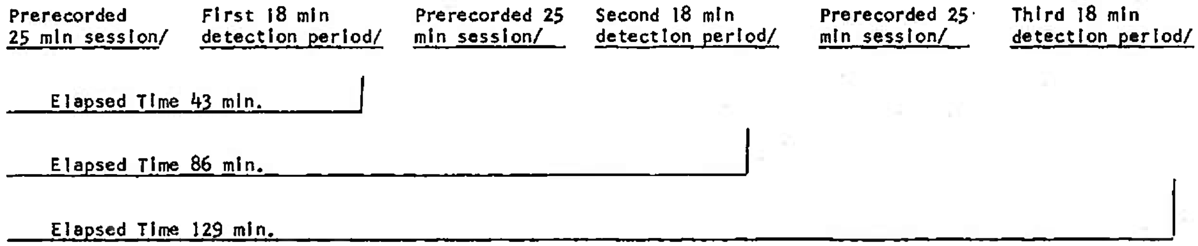

Fig. 3. Schedule for Simulated Sonar Watch.

<u>Specific Procedures for Collecting Data During Pretest and Measurement Periods.</u>

Subjects were individually seated at the sonar stack console and asked to report bearing, to the nearest degree, of a target presented in a simulated ship noise background.

Target signals were presented below the level of the background, creating appropriate negative S/N ratios.* Initial trials on each target were presented with the target masked well below operator threshold and if detection was not made within three sweeps across the target, the trial was terminated, though the subject was not informed of any termination other than "please continue search." The experimenter then raised the signal level of the target by 2 dB (causing a lesser negative S/N ratio), continuing this procedure until the operator reported his first accurate bearing ($\pm 5°$ accuracy). When a contact bearing was reported, it was recorded along with the S/N ratio and the trial terminated though the search was continued.

**In this context then a greater S/N would imply that the target level was further decreased in the background noise. A low S/N would be found when the target level is nearly as loud as the background.*

If the bearing reported was accurate ($\pm 5°$): E considered the trial terminated, bearing was randomly changed, and the signal level of the target was lowered 2 dB (higher S/N) on the next trial. If the bearing reported was inaccurate: the trial was terminated, target level was raised 2 dB (lower S/N), and the next detection trial was begun at the same or at another bearing.

Criterion was either 2 accurate detections out of 4 at a specific S/N (2/4 = 50% detection probability) or 2 accurate detections out of 2 (2/2 = 100% detection probability) at a specific S/N along with 3 inaccurate detections (0/3 or 1/4 = <50%) at the next more difficult S/N. From this information the SN ratio at 50% detectability was derived. All targets were presented serially, and target bearing, although otherwise random, was never at the extreme 10° of the 180° sweep.

The criterion of not more than three sweep passes during a trial (automatic trial termination after three sweep passes across the target) was employed since, if after the third pass the operator had failed to detect the target, its level was assumed below the 50% point of detection probability and the next

higher S/N level should be presented. Using this procedure, misses and false alarms (incorrect bearings) are grouped. This we believe is a more realistic assumption since under pretest conditions where the operator knows that a target is always present (though at times below threshold) he is more likely to report some bearing rather than to report no contacts at the termination of his third sweep across the target.

These same procedures were used during the 18-min measurement sessions the following day. Operators were given no indication of the switch-over from the prerecorded 25 min session to the 18 min evaluation period, E being hidden from the operator's view. During all sessions, contacts were confirmed or negated in accordance with their presence or absence at the reported bearing. During the 129 min sonar watch it was requested that the operator not wear a wristwatch and no means of estimation of elapsed time was provided (a stopwatch was available but only for turn counting purposes).

RESULTS AND DISCUSSION

Results of an analysis of variance (repeated measures) showed no significant change in target detection ($p < .75$) after elapsed times of 43, 86 and 129 min. Further, no significant difference was found between such data collected over the three evaluation periods and that collected on the same contact the day prior to watch standing, ($p < .75$). Operators ranged in sonar experience from 1 yr to 11.5 yrs, the average being 4.76 yrs (standard deviation 3.54 yrs). A Pearson product moment correlation, comparing average target detection of each operator with years experience showed it not different from 0 correlation at the 10% level of confidence ($r = -.108$), (i.e., within the limits of this study, the more experienced operators did not excel in target detection.)

Such results indicate that under conditions where operator vigilance is maintained at a moderate level, operator initial detection performance is not degraded over a 2 hr period. It should be pointed out, however, that operators had no knowledge of elapsed time and perhaps their performance would have been degraded under conditions where such information was available. Further, the lack of correlation between years experience in sonar and sonar detection performance is common finding indicating that at least in initial detection, years sonar experience is not the determining factor.

SUMMARY

Eighteen experienced sonar operators, when exposed to conditions of simulated sonar watch over a 129-min detection period, showed no significant change in target detection ($p < .75$) after elapsed search times of 43, 86 and 129 minutes. Further, no significant difference was found between such data and that collected on the same simulated contact the day prior to watchstanding ($p < .75$). Such results indicate that under conditions where operator vigilance is maintained (operators were presented six contacts at random intervals during each 43 min segment) oper-

ator initial detection performance is maintained over a 2 hr period. In addition, no correlation ($p < .10$) was found between an operator's months of sonar experience and his performance averaged across the three measurement periods.

REFERENCES

1. Broadbent, D.E. The General Nature of Vigilance in Perception and Communication. New York: Pergamon Press, 1958, pp. 108-139.

2. Guilford, J.P. Fundamental Statistics in Psychology and Education. New York: McGraw-Hill, 1956.

3. Nordstrom, W.C. A method of producing a bearing controlled gating signal. USL Tech. Memo No. 1210-40-56, of 17 April 1956.

4. Pastore, M.J. Investigation of human factors for improving sonar operators' performance. NUSC Tech. Memo No. PA3-193-72, of 25 May 1972.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY Naval Submarine Medical Center	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

AURAL DETECTION PERFORMANCE OVER A 129 MINUTE SIMULATED SONAR WATCH

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Interim report

5. AUTHOR(S) *(First name, middle initial, last name)*

Joseph S. Russotti
and
Ronald E. Greeb, STI(SS)

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
12 September 1973	7	4

8a. CONTRACT OR GRANT NO. b. PROJECT NO. MF51.524.004-9010DA5G c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NSMRL Report Number 754 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Submarine Medical Center Box 600 Naval Submarine Base Groton, Connecticut 06340

13. ABSTRACT

Experienced sonar operators were exposed to conditions of simulated sonar watchstanding over a 129-min period. Successive measurements on the same non-alerted contact taken every 43 min during the detection period showed no significant change in initial detection. These results indicate that under conditions where the operator's vigilance is maintained by a not-unusual frequency of contact (operators were presented six contacts at random intervals during each 43-min period) no change in operator initial detection performance is encountered.

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0102-014-6600

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Passive Aural Detection Sonar Operator Performance Sonar Watchstanding Auditory Vigilance						